MAJOR, MINOR AND TRACE ELEMENT GEOCHEMISTRY OF TAIWAN BEDROCK

Senior Thesis

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By

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Abstract

Recent sediment flux estimates have shown that rivers draining Taiwan and other high-standing oceanic islands in Austral-Asia contribute a significant fraction of the total sediment flux to the oceans. Previous studies on weathering rates on these islands of the Pacific Ocean have revealed that although the ratio of chemical to physical weathering is low, the absolute rates of chemical weathering are some of the highest observed in the world. Chemical weathering studies in watersheds from these locales have traditionally focused on the comparison of water, sediment, and rock geochemistry. However, preliminary studies in Taiwan have been limited by a lack of sufficient bedrock geochemical data. Therefore, the determination of local bedrock geochemistry in Taiwanese watersheds is critical to achieve an understanding of these weathering processes.

In April and July of 2005, a total of 23 rock samples consisting of meta-sandstones, various grades of metamorphosed shales, and mafic igneous rocks were collected in watersheds throughout Taiwan. The samples were analyzed by x-ray fluorescence (XRF) spectrometry in order to determine their major, minor and trace element composition. Prior to analysis, the outer weathered surfaces of the samples were removed in order to achieve a true chemical composition. During sample preparation, clean room procedures were also utilized so that the samples could be analyzed for organic carbon at a future time. The rock data provide an enlarged database for future comparison to stream water sediment data in order to determine relative chemical weathering intensities of the sediment.

Acknowledgements

I would like to thank Dr. Terry Wilson for her insight on the plate tectonics of Taiwan. Sreenivas Bhattiprolu was very helpful in analyzing my samples with the X-ray fluorescence spectrometer. Thanks to Dr. Anne Carey for her continued enthusiasm and insight throughout the whole process. A special thanks to Steve Goldsmith for his energetic persistence in assisting my research. I would also like to thank Christin Eulberg for her ongoing support during the research process. This research was supported in part by the National Science Foundation grant EAR 0309564.

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Figures and Tables

Introduction

Previous studies on weathering rates of high standing islands (HSIs) have shown some of the highest observed rates of chemical weathering in the world (Lyons et al. 2005). However, attempts to correlate these rates to bedrock lithology have often suffered due to a lack of bedrock geochemical data. The purpose of this research is to complement existing water and sediment data for Taiwan with bedrock geochemical data. The data also have the potential to yield valuable information regarding the origin of the rocks which currently makeup the island.

The island's rapid uplift rates of 1.5-10 mm/yr (Dadson et al. 2003) lead to high rates of physical erosion. Therefore, it exposes fresh bedrock to the environment that, in turn, gets chemically weathered at some of the highest rates in the world. The subsequent chemical weathering of the local bedrock is the "primary source of most solutes to the terrestrial and aquatic ecosystems" (Carey et al. 2005, p. 215). In order for these high rates of chemical weathering to occur, an extreme weathering environment must be present, and Taiwan's subtropical to tropical locality leaves it very susceptible to some of the heaviest amounts of rainfall in the world, as much as ~4290 mm/yr (Lin et al. 2000).

Geologic Setting

In order to discover the implications of the resulting bedrock geochemistry, the geologic background of the island of Taiwan must be truly understood. The island of Taiwan is simply the southeastern extension of the Eurasian plate and only separated from mainland China by water due to uplift at the collision zone. The formation of Taiwan was due to the collision of the Eurasian plate with the Philippine Sea plate and subsequent uplift (Liu et al. 2001). The accretion of the Coastal Range (a pre-existing volcanic arc) onto the eastern portion of Taiwan explains the complex nature of the region's tectonism. This pre-existing volcanic arc was formed due to the subduction of the once oceanic Eurasian plate under the Philippine Sea plate. Ho (1975) explains the stages of collision that led to the accretion of the Coastal Range onto mainland Taiwan (Fig. 1). The Luzon volcanic arc formed by the subduction of the Eurasian plate under the Philippine Sea plate, then the successive westerly movement of the Philippine Sea plate collided it with the eastern tip of the Eurasian plate which resulted in regional uplift. The resultant island of Taiwan was then formed above sea level so that the island arc chain could then be "scraped" off onto Taiwan due to plate tectonics (Fig. 2).

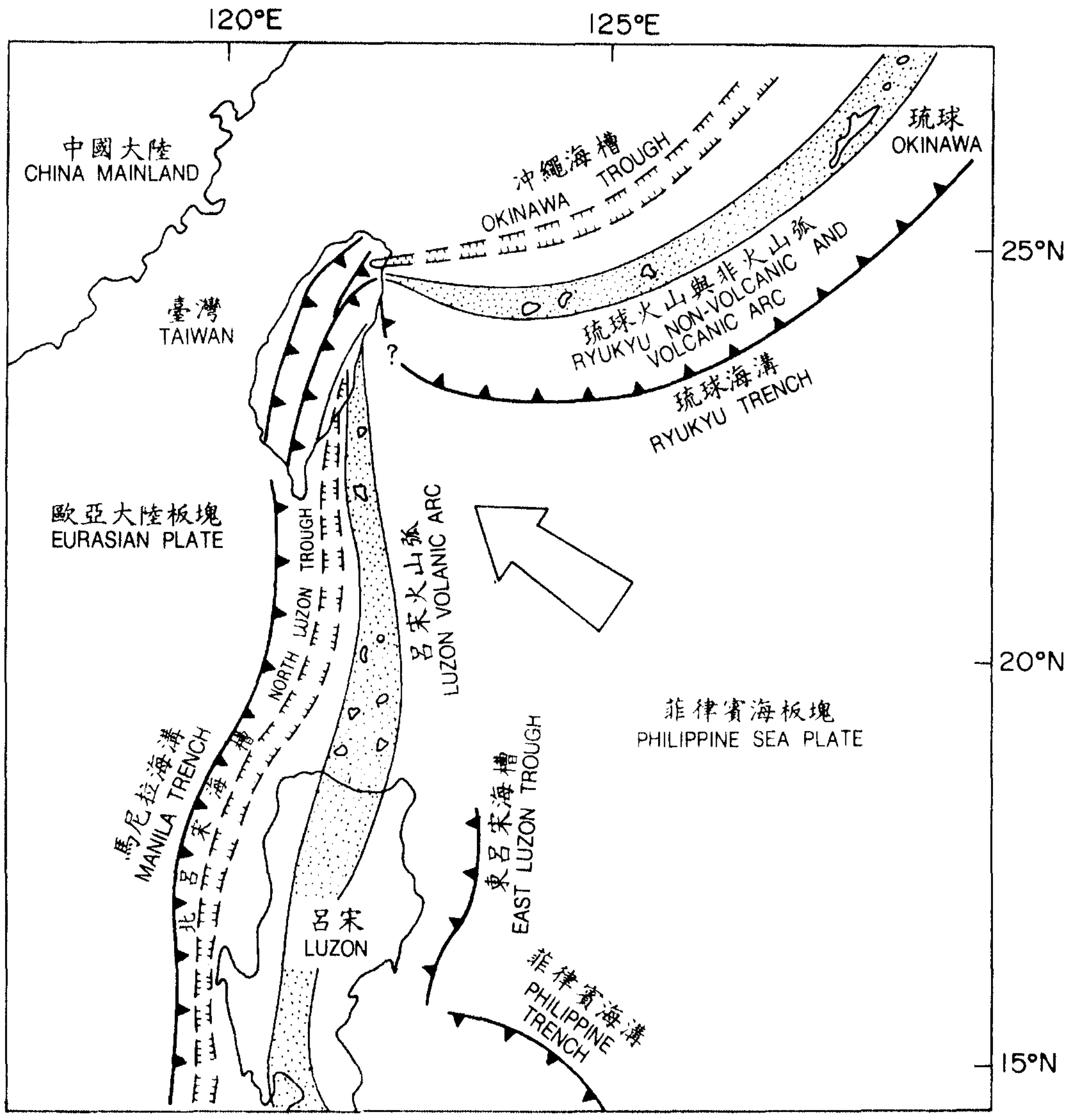

Figure 1. Structural Relations of Taiwan and Surrounding Volcanic Arcs (Ho 1975)

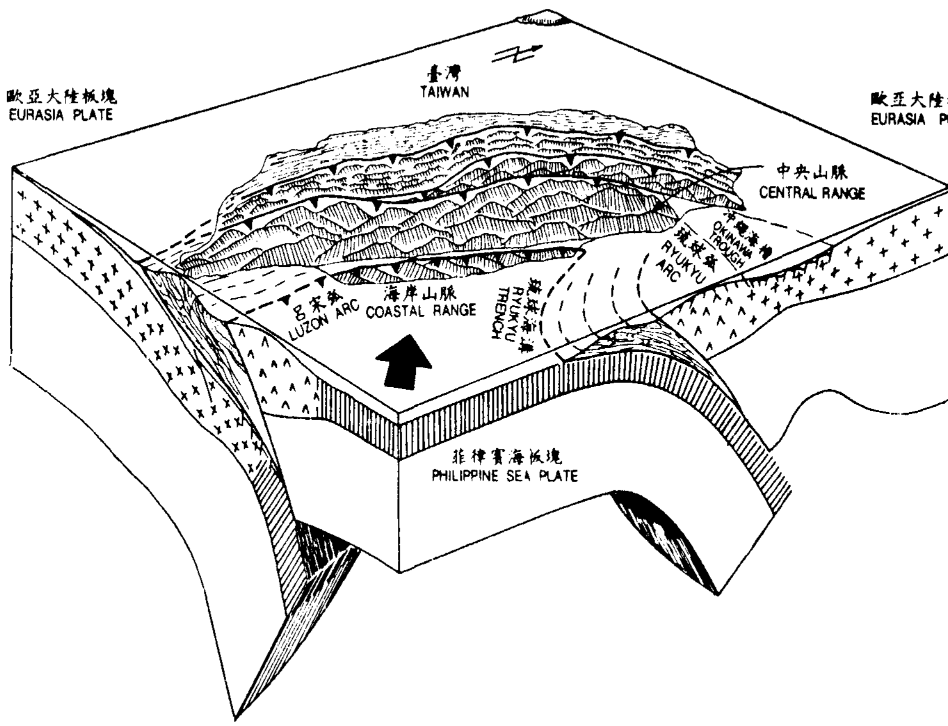

Figure 2. Plate tectonics of the Taiwan Region (Ho 1975)

It is the compression of the Eurasian plate and Philippine Sea plate that form the mountainous region of Taiwan. Rapid uplift rates of ~1.5-10 mm/yr and the succession of thrust faults located along the length of the Central Range can be attributed to this collision. Because the two plates are colliding at a rapid pace (Philippine Sea plate moving 7 cm/yr), thrust faults along the Central Range lead to regional metamorphism (Fig. 3).

Zircon fission track dates were presented in support of the continuing southwesterly movement of the Philippine Sea plate as it continues to collide with the Eurasian plate. The work of Liu et al. (2001) gives evidence that the formation of the Central Range of Taiwan originated in the western geosynclinal basin and then continued east. Data compiled along the north-south trend of the island were given that supported an age distribution reflecting a southward propagation of the arc-continent collision and subsequent uplift-and-denudation (Liu et al. 2001). The ages range from 1 Ma - 5 Ma (the time of the last major orogenic event, the Penglai orogeny) along east-west transects measured along the length of the island.

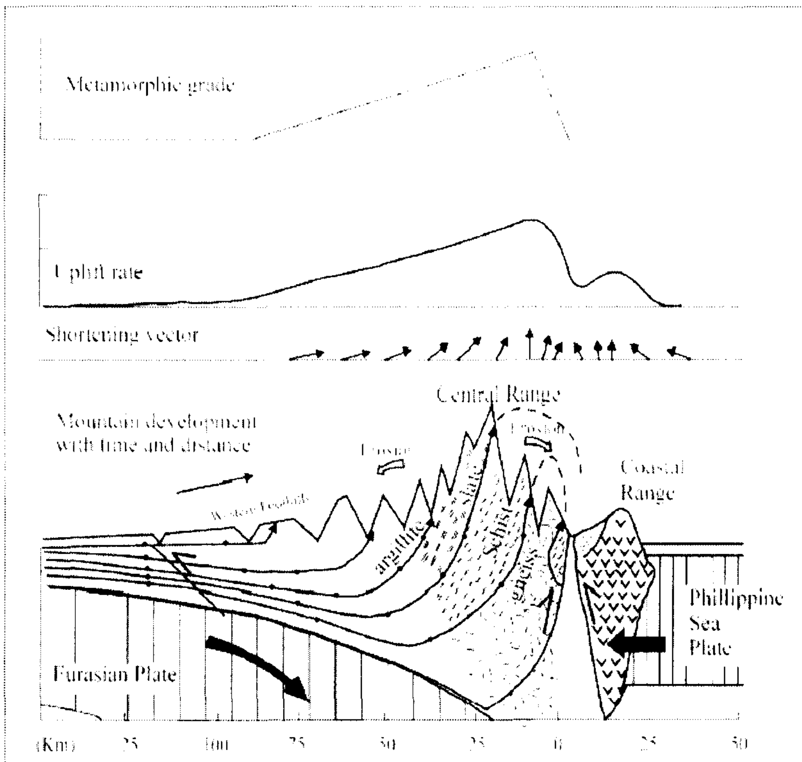

Figure 3. Cross-section view of Central Range Thrust Faults (from Liu et al., 2000)

Methods

Sampling Methods

A total of 23 rock samples were collected from rivers and their tributaries in different localities spanning the eastern coast of Taiwan. These areas include the Hsiukuluan-Hsi watershed of the Coastal Range, and the Lanyang-Hsi and Fushan watersheds of the Central Range on the northern end of the island (Fig 4).

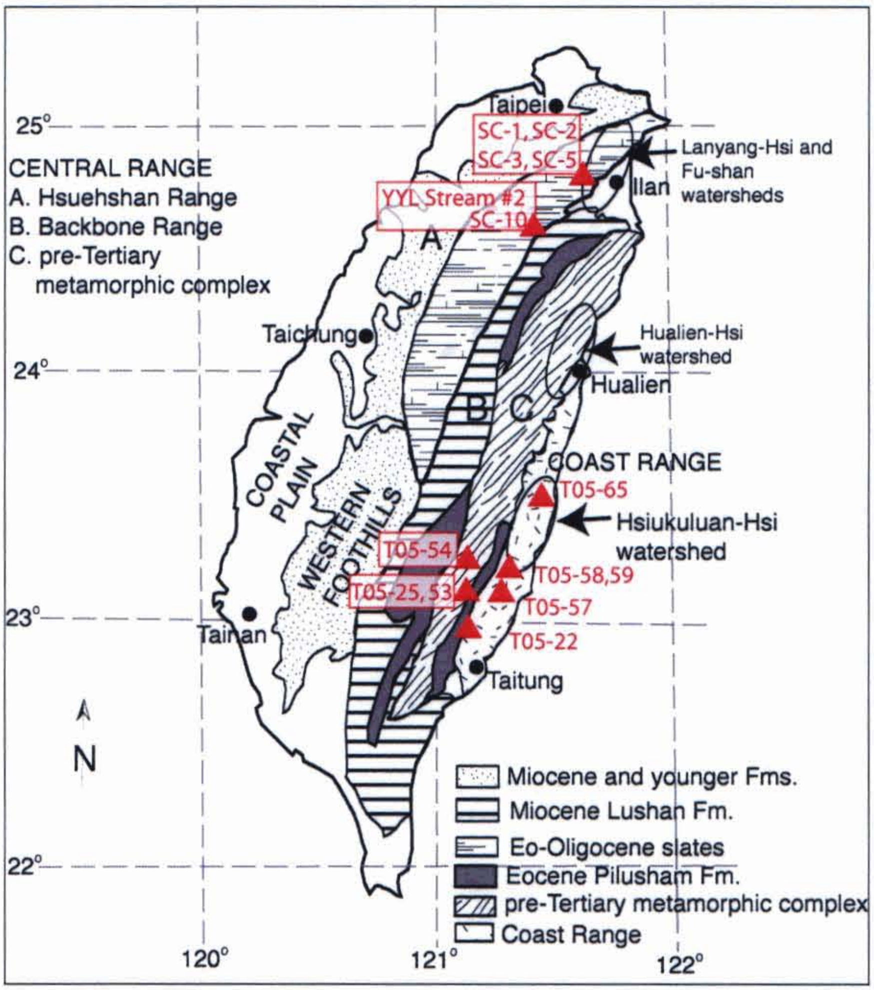

Figure 4. Geologic Map of Taiwan showing sampling localities (triangles) of most rocks analyzed in this study. After Clark et al. (1993) and Suppe (1984). Integrated with the use of Google™ Earth.

A variety of rock types was collected such as meta-sandstones, various grades of metamorphosed shales, intermediate-mafic igneous rocks, sedimentary sandstones and soft shales. Care was taken to collect rock samples from portions of outcrops that appeared least weathered. The samples were placed in new plastic Ziploc® bags and shipped to Ohio State for processing and analysis. Most of the rocks were taken from bedrock within the banks of the waterways, but the mafic igneous rocks were collected as bedload within the streams.

Lab Procedures

The rock samples were first taken to the rock saw in order to cut off the weathered surfaces. It is necessary to get a true parent lithology and not have any weathered surfaces that would affect the elemental analysis. Most of the sedimentary rocks showed evidence of being weathered through. The evidence consisted of secondary Fe oxidation that led to a visible differentiation in color along with a more friable nature of the rock. The resulting fresh surfaced blocks were between ~45-60g which allowed for enough powder for multiple analyses if necessary. The dried samples were crushed in an alumina shatterbox for a minimum of 10 minutes until a grain size less than 2μm was achieved. Of note, clean room procedures were followed during the crushing process along with the subsequent sample preparation.

Major Element Analyses

A 1.0g aliquot of dried ignited sample was mixed with approximately 10g of SpectroCertified® Pre-Fused Fusion Flux Lithium Tetraborate (100% $Li_2B_4O_7$) flux into a disposable plastic crucible and mixed with a stainless steel spatula until visible homogeneity was achieved. The sample-flux mixture was subsequently placed in a platinum crucible and loaded into a Phillips® Perl'x 3® automatic bead machine where it was ignited for 4 minutes at 800°C, 4 minutes at 1100°C, and 8 minutes at 1150°C until complete melting of the sample was achieved. The molten sample was poured into a platinum casting dish and air cooled for 4 minutes to allow for solidification. The resulting fused bead was observed for visual deformities (i.e., cracks, incomplete sample dissolution). Any sample showing imperfections was discarded.

Prior to analysis, a 12 point calibration curve with USGS standards was created for the 1:10 sample/flux ratio samples. Standards for the 1:10 major element analysis were also analyzed as samples approximately every three samples and were found to be within ±1% accuracy and usually better than ±0.5% of values provided by the USGS for major elements. In addition, a standard was analyzed for major oxides as a sample 3 times and used to determine analytical precision for each element. Major elements were analyzed as samples and were found to have a precision within ±1% of the values provided. Precision and accuracy data associated with the major element XRF analyses can be found in Appendix A.

The fused beads were analyzed in a PANalytical® MagiX Pro® x-ray fluorescence (XRF) spectrometer with a PW2540 VRC sample changer to determine major elemental oxide composition. Samples were analyzed three times and an average concentration was determined and normalized to the sum of the concentrations using the LOI data determined above. Relative standard deviations for the triplicate runs for major oxides were all within 3% and the majority less than 0.5%. Two runs gave standard deviation values of 8% (MnO) and 15% (MnO), which was attributed to concentrations being close to the limit of detection (LOD) value. Accuracy values determined using USGS standardized BCR-2 (Columbia River basalt) were well within USGS error ranges which helps to solidify the results produced by the PANalytical MagiX PRO PW2440 XRF spectrometer.

Trace Element Analyses

A 12.0g aliquot of dried sample was mixed with 3.0g of SpectroCertified® Blending, Grinding and Briquetting Additive SpectroBlend® 44μ Powder (chemical composition: 81.0% C, 13.5% H, 2.9% O, and 2.6% N) flux and subsequently mixed in a shatterbox for 1 minute to ensure sample homogeneity. The sample-flux mixture was placed in a stainless steel die and loaded into a SPEX® 3600 Xpress® automatic press. The press was preset for a hold time of three minutes at 25 tons of pressure and a release time of one minute to form a pressed pellet. The pressed pellet was observed for visual deformities (i.e., crack, chips, etc.) with any samples showing imperfections discarded.

Prior to analysis, a 14 point calibration curve for the 1:4 sample/flux ratio samples was created using 10 USGS standards and seven Geological Survey of Japan (GSJ) standards. The calibration curve was utilized with SuperQ® software with ProTrace® package. Trace element standards were analyzed as samples with the same frequency as the major elements and were found to have an accuracy range of 1-12% with the majority better than ±5% of the values provided. Abnormally poor accuracy for Ba (up to ±12%) was observed and can be attributed to the standard concentration being close to LOD value. In addition, a standard was analyzed for minor and trace elements as a sample 3 times and used to determine analytical precision for each element. Trace element standards were analyzed as samples with the same frequency as the major elements and were found to have a precision within ±3% with the majority better than ±1% of the values provided. Accuracy values determined using USGS standardized BCR-2 (Columbia River basalt) and BHVO-2 (Hawaiian Volcanic Observatory basalt) were well within USGS error ranges which helps to solidify the results produced by the PANalytical MagiX PRO PW2440 XRF spectrometer. Precision and accuracy data for the trace element XRF analyses are in Appendix B.

The pressed pellets were subsequently analyzed in the XRF spectrometer to determine elemental composition. Samples were analyzed three times and an average composition was determined for use in this study. Relative standard deviations for the triplicate runs for trace elements were usually within ±5% with the majority less than ±2%. However, Sc, Ba and Co each had one extreme value of ±63%, ±18% and ±26%, respectively. High standard deviation values can be attributed to the concentration being close to the LOD value.

Loss on Ignition Analysis

A loss on ignition (LOI) analysis was conducted on 14 of the 21 rocks in order to determine the percentage of sample composed of organic material, carbonate minerals, and bound water. Total LOI values for the remaining 7 rocks were determined directly by the XRF spectrometer. The purpose of determining LOI manually was to rid the rock of any weathering products on the sedimentary rocks that might affect overall elemental composition as determined by XRF analysis.

For total LOI determination, an aliquot of approximately 3.0-3.5g of crushed sample was re-dried at 110°C, placed in a Coors® alumina crucible, and weighed prior to ignition. The sample was ignited in a muffle furnace for 1 hour at 1025°C and gradually cooled over a four hour period back to 110°C where a final weight was determined. Total LOI was calculated as follows:

$$Loss\ on\ Ignition = \frac{W_C + W_S - W_F}{W_S}\ x\ 100$$

W_C = Weight of empty crucible
W_S = Initial weight of sample
W_F = Final weight of sample and crucible

Instrumental results calculated after ignition never resulted in an LOI value greater than 5.44%.

Table 1. Loss on Ignition Measurement

Sample #	Rock Type	*A* mass of empty crucible before heating (g)	*B* mass of sample before heating (g)	*C* mass of crucible and sample after heating (g)	L.O.I. [wt%] 100 x [(*A*+*B*-*C*)/(*B*)]
SC-1	Sedimentary	50.9099	2.1420	52.9415	5.15%
SC-2	Sed. to light meta.	50.7191	3.5469	54.1071	4.48%
SC-3	Sed. to light meta.	50.9127	3.5012	54.2350	5.11%
SC-5	Sedimentary	51.7194	3.1544	54.7090	5.22%
T05-54	Sedimentary	51.0416	3.2833	54.2249	3.05%
T05-57A	Sedimentary	50.5847	3.5748	54.1008	1.64%
SC-1 FUSHAN	Sed. to light meta.	19.4172	3.0275	22.2970	4.88%
YYL STREAM #2	Sed. to light meta.	22.0603	3.2291	25.2660	0.72%
DR. KAO ARGILL./SCHIST	Metamorphic	22.0551	2.9883	24.8939	5.00%
WULING PRISON	Metamorphic	19.8911	3.0970	22.8335	4.99%
CSAOLING WATERSHED	Sedimentary	19.0353	3.0681	22.0424	1.99%
SAMPLE SITE R	Sedimentary	19.4170	3.1337	22.4887	1.98%
T05-65	Sedimentary	51.0834	3.2085	54.1174	5.44%
T05-22	Igneous	51.0424	3.0715	53.9472	5.43%

Results

Sedimentary Rocks

An important observation is the almost complete depletion in CaO (Table 2). With the exception of the igneous rocks and T05-57A, other rocks analyzed showed zero or nearly zero CaO (average limit of detection 21.99 ppm). In terms of %MgO, the sedimentary rocks are split into two ranges, the 2.40-3.01 range and the 0.127-0.883 range. The sample locations of the rocks collected show no correlation to these two ranges. In all ten sedimentary rock samples Mn, Mg, P, Ni, Cu, Sr and Ba were depleted relative to Deep Sea Clay while elements like Si and Zr were still relatively close to these unweathered values. With the exception of T05-54 and T05-57A, the sedimentary rocks are very highly enriched in Rb, Zr and Ba in relation to the igneous rocks. It is possible that T05-54 and T05-57A were incorrectly identified in hand sample as sedimentary rocks. Both were collected in the southern portion of the island and the rest of the sedimentary rocks were collected in the northeastern section in the Lanyang-His and Fu-shan watersheds. The sedimentary rocks collected showed an overall depletion when normalized to the Upper Continental Crust values of Taylor and McLennan (1985) and the Deep Sea Clay values of Martin and Whitfield (1983) while only a few elements are enriched (Figures 5 and 6).

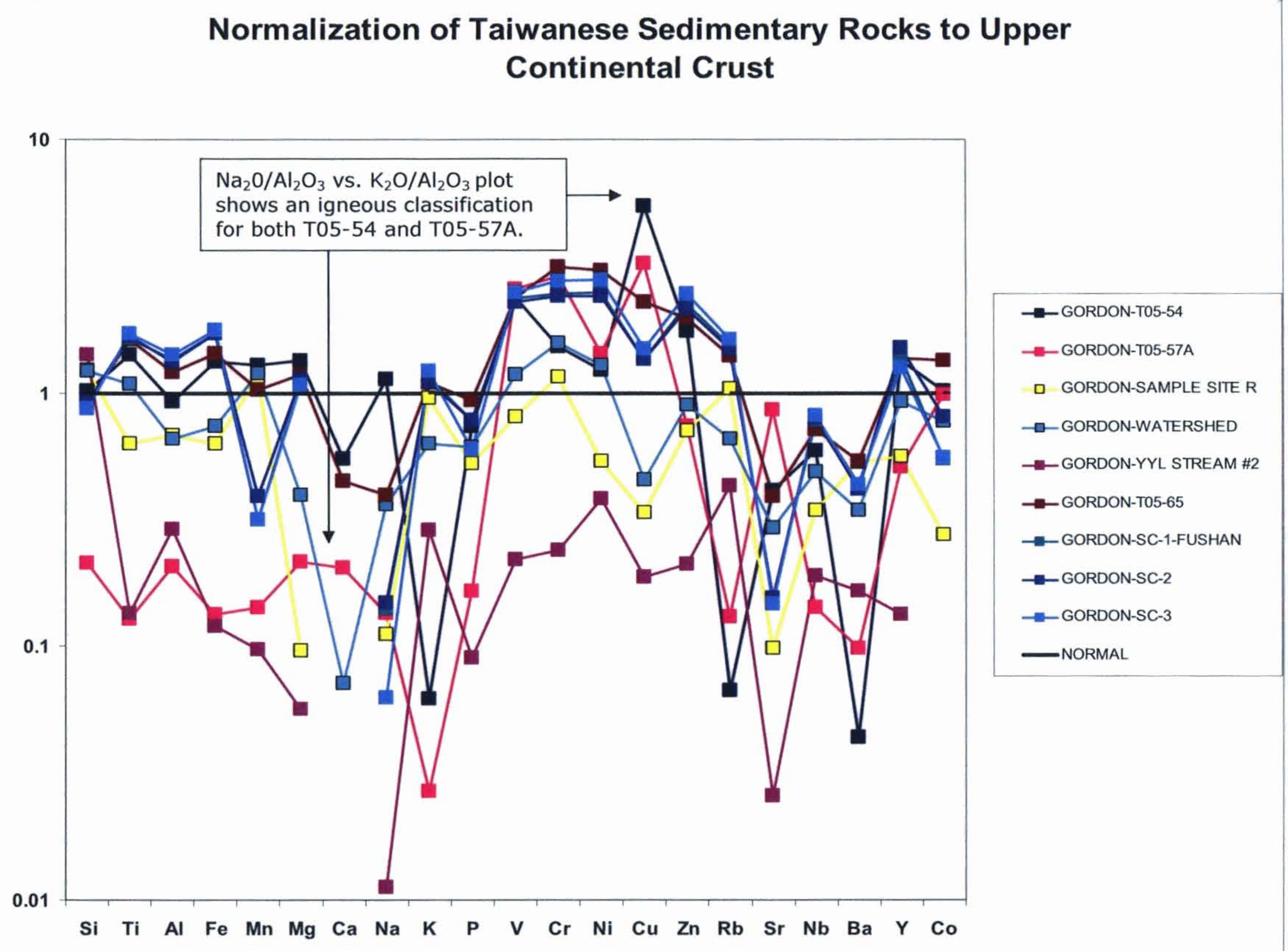

Fig. 5. Taiwanese sedimentary rocks normalized to UCC values of Taylor and McLennan (1985).

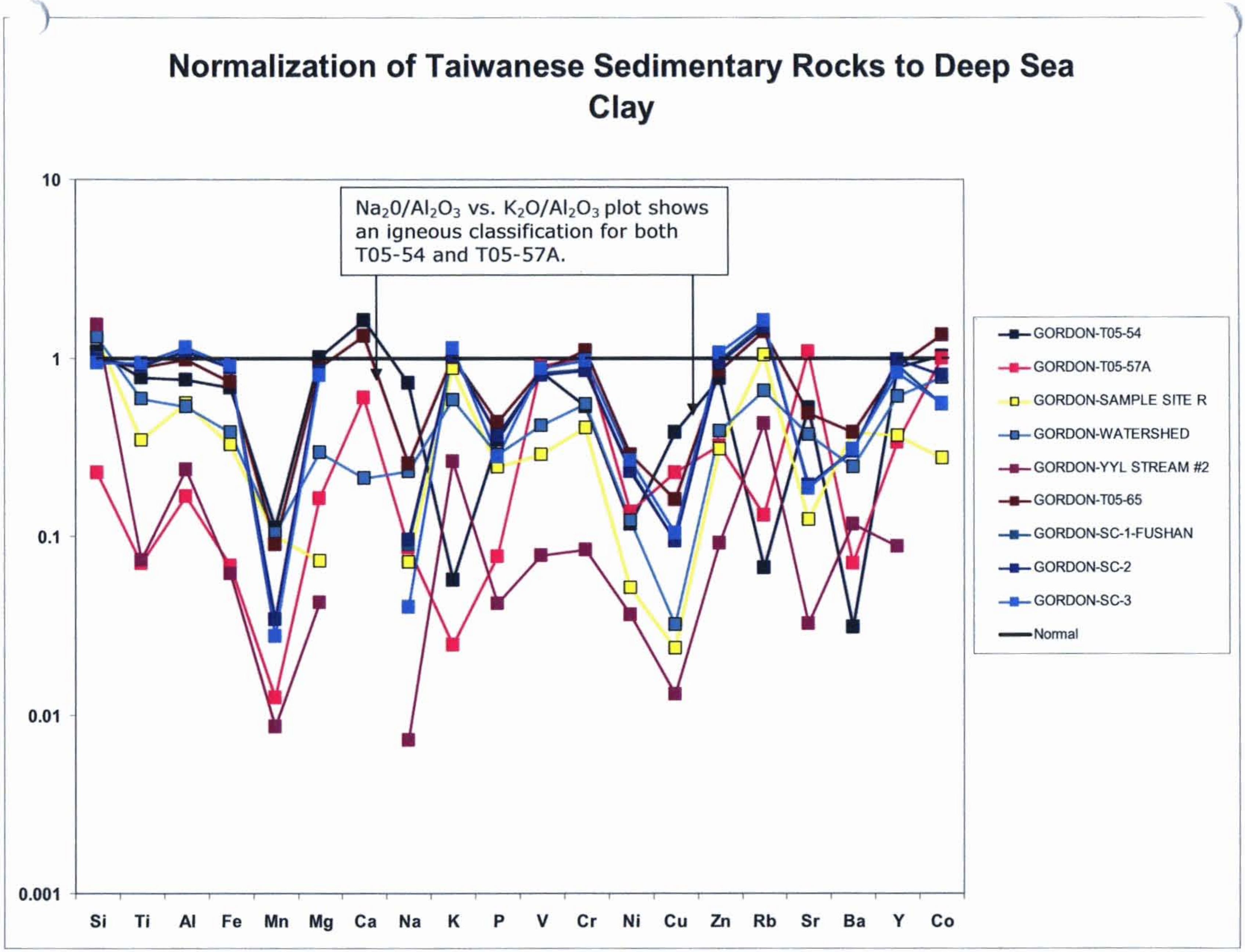

Fig. 6. Taiwanese sedimentary rocks normalized to deep sea clay values of Martin and Whitfield (1983).

Igneous Rocks

The igneous rocks showed a definite island arc signature of the inclusion of deep sea clays and their associated fluids into the arc volcanics (Tables 2 and 3). The subduction of the Eurasian plate under the Philippine Sea plate introduced clay sediments into magma production at depth, which is why we see a sedimentary influence on their chemical makeup. When normalized to Upper Continental Crust values (Taylor and McLennan, 1985) there is a distinct pattern of element composition. K, Rb, Zr, Nb, and Ba are all depleted relative to upper continental crust values and there is a related trend in the curves normalized to NMORB (Normal Mid-Ocean Ridge Basalt) values. The igneous rocks show an enrichment of K, Rb, Nb and Ba when compared to the Normal Mid-Ocean Ridge Basalts (Sun & McDonough, 1989) (Figs. 7 and 8). T05-25 stands out as very depleted in K_2O and slightly depleted in Na_2O relative to other igneous rocks that were collected in the same region such as T05-22 and T05-53.

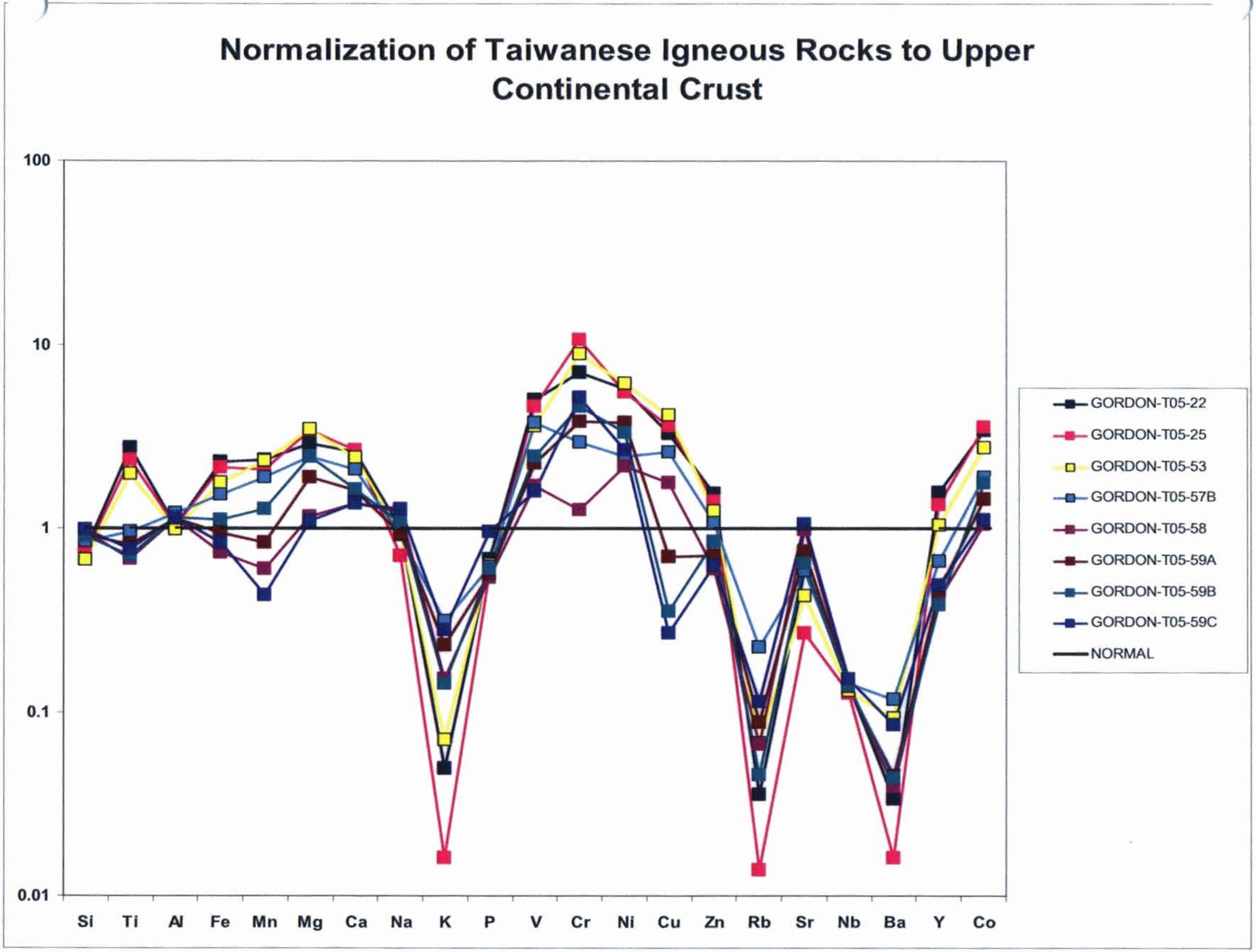

Figure 7. Taiwanese igneous rocks normalized to UCC values of Taylor and McLennan (1985).

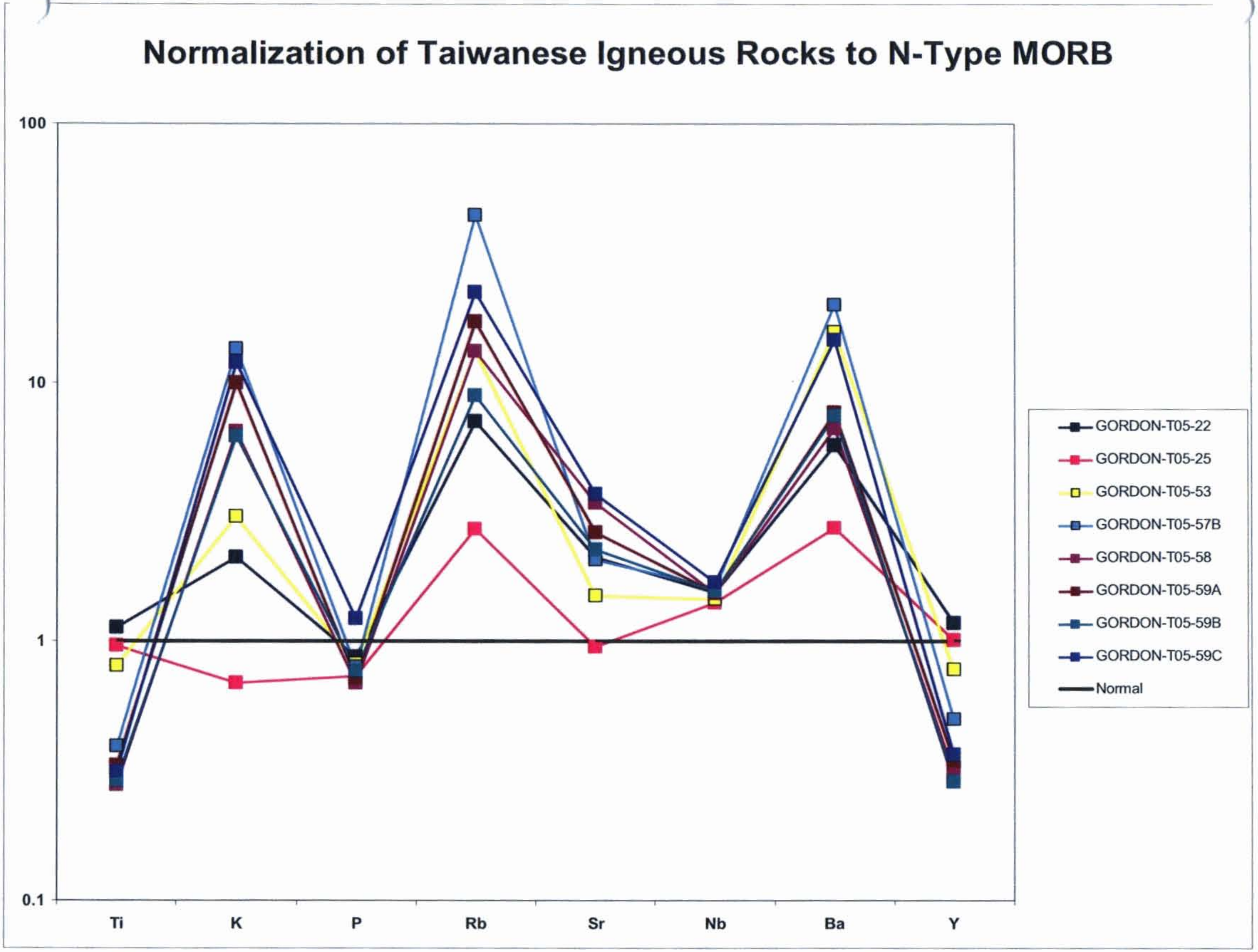

Figure 8. Taiwanese igneous rocks normalized to NMORB values of Sun & McDonough (1989).

Metamorphic Rocks

The metamorphic rocks consisted of two meta-sandstones which were very high in SiO_2 (84.1% and 89.6%), and two metamorphosed shales with a low SiO_2 (59.9% for both). The two metamorphic types are also distinguishable in every other element but K. This could be due to a relatively low abundance of K in the original rock and is therefore independent of the amount of K that is capable of being weathered out. The meta-sandstones showed a more depleted trend while the argillite/schist was comparatively enriched when compared to the meta-sandstones (Figs. 9 and 10). YYL Stream #2 and SC-10 are from the same sampling locality and have the same general composition, but SC-10 (Meta.) has almost twice as much K_2O (1.53%:0.890%) and almost half as much Fe_2O_3 (0.316%:0.530%) as YYL Stream #2.

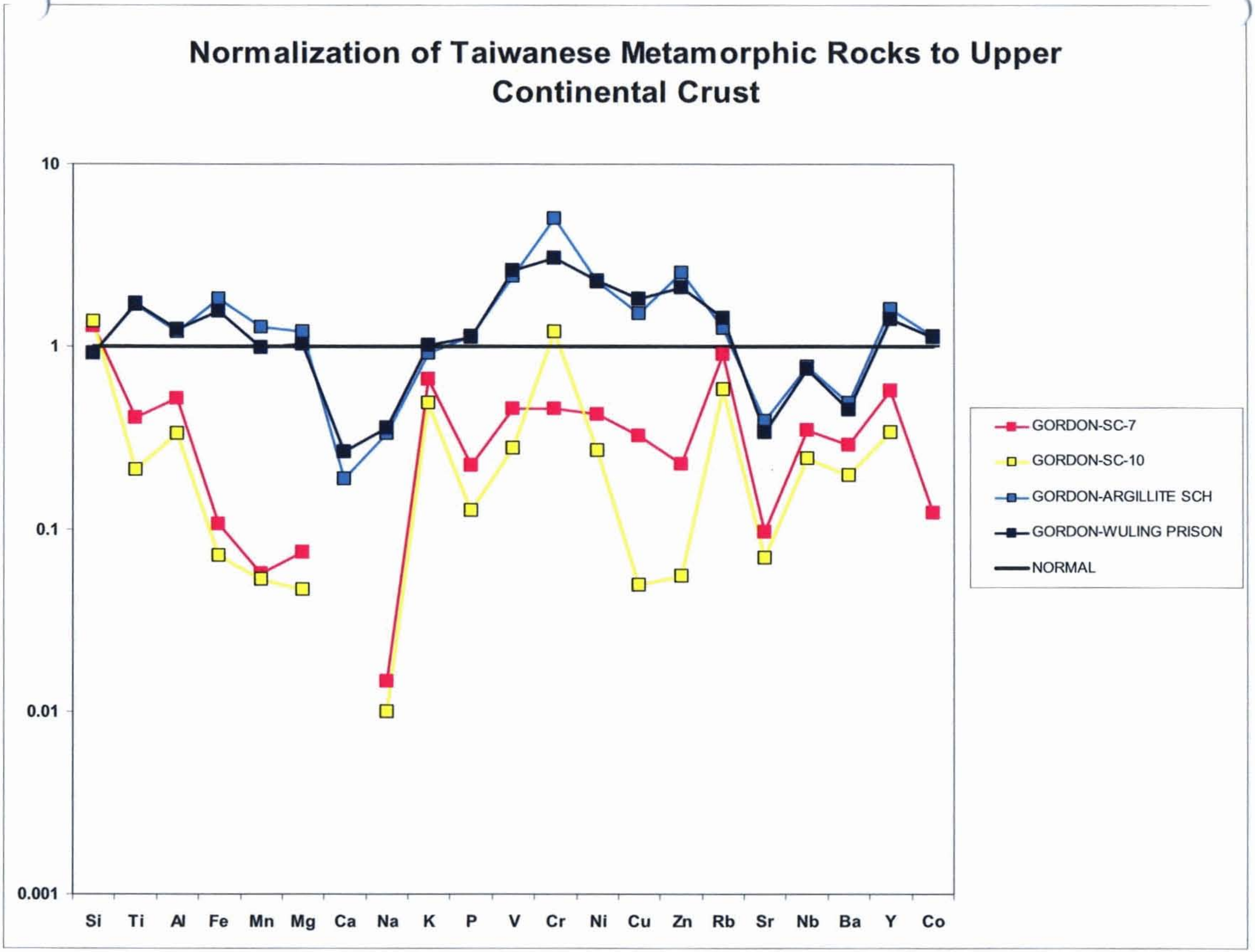

Figure 9. Taiwanese metamorphic rocks normalized to UCC values of Taylor and McLennan (1985).

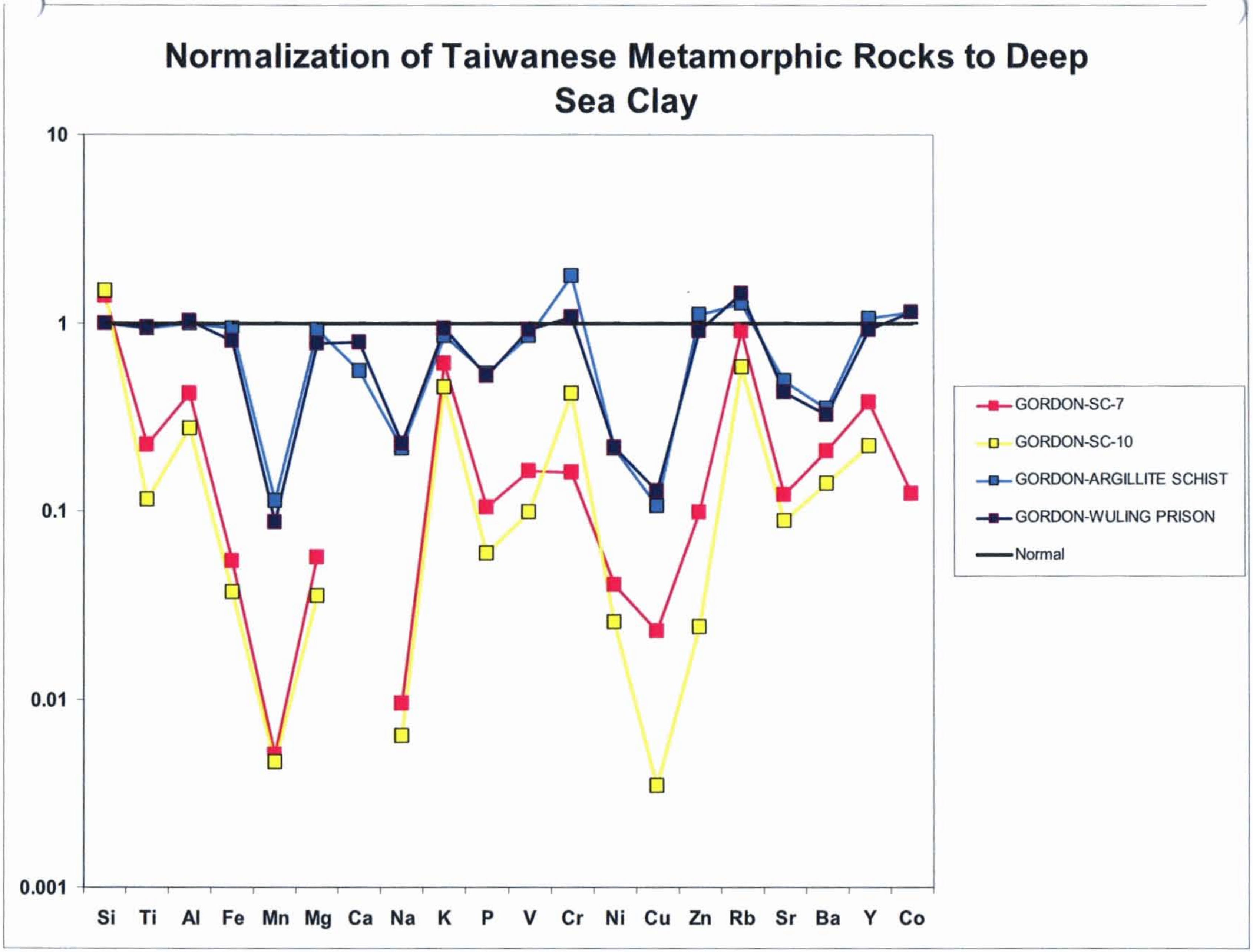

Figure 10. Taiwanese metamorphic rocks normalized to deep sea clay values of Martin and Whitfield (1983).

Table 2. Major Element Composition

(Average of 3 runs)

Sample Name	SiO_2 (%)	TiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	P_2O_5 (%)	Total Majors (%)
						Sedimentary					
T05-54	65.8	0.736	13.5	5.88	0.0873	3.01	2.26	3.90	0.193	0.111	95.4%
T05-57A	64.6	0.401	16.0	4.14	0.0754	2.93	6.00	3.48	0.694	0.108	98.4%
T05-65	59.7	0.844	17.6	6.33	0.0700	2.65	1.85	1.37	3.38	0.140	93.9%
SC-1-FUSHAN	59.7	0.851	19.8	7.56	0.0216	2.50	0	0.487	3.54	0.117	94.5%
SC-2	59.6	0.868	19.5	7.53	0.0267	2.54	0	0.513	3.44	0.117	94.1%
SC-3	56.6	0.891	20.7	7.79	0.0215	2.40	0	0.217	3.79	0.0895	92.5%
SAMPLE SITE R	80.4	0.327	9.98	2.79	0.0784	0.216	0	0.386	2.95	0.0787	97.2%
WATERSHED	79.3	0.562	9.63	3.27	0.0813	0.883	0.295	1.25	1.95	0.0915	97.3%
YYL STREAM #2	92.3	0.0702	4.25	0.530	0.00662	0.127	0	0.0387	0.890	0.0136	98.2%
SC-1	84.0	0.320	7.95	2.19	0.0555	0.409	0.0982	0.559	1.93	0.0613	97.5%
SC-5	85.2	0.317	7.28	2.00	0.0478	0.473	0.131	0.617	1.59	0.0554	97.7%
						Igneous					
T05-22	49.2	1.43	15.1	10.1	0.160	6.54	10.7	3.41	0.153	0.102	96.9%
T05-25	47.4	1.22	14.9	9.49	0.142	7.63	11.0	2.44	0.0499	0.0855	94.4%
T05-53	43.4	1.02	14.5	7.83	0.158	7.81	9.95	3.30	0.219	0.0962	88.3%
T05-57B	55.2	0.500	17.7	6.77	0.128	5.49	8.61	3.20	0.975	0.0931	98.7%
T05-58	62.3	0.353	16.6	3.25	0.0407	2.60	5.67	4.26	0.468	0.0812	95.6%
T05-59A	59.7	0.421	16.6	4.20	0.0571	4.25	6.68	3.23	0.720	0.0842	95.9%
T05-59B	58.8	0.370	16.7	4.92	0.0868	5.52	6.74	3.69	0.447	0.0901	97.4%
T05-59C	64.4	0.401	16.8	3.70	0.0295	2.47	5.63	4.41	0.867	0.144	98.9%
						Metamorphic					
SC-7	84.1	0.213	7.61	0.468	0.00389	0.168	0	0.0509	2.05	0.0334	94.7%
SC-10	89.6	0.109	4.91	0.316	0.00360	0.105	0	0.0344	1.53	0.0190	96.7%
ARGILLITE SCHIST	59.9	0.886	17.7	8.03	0.0874	2.73	0.778	1.16	2.86	0.172	94.4%
WULING PRISON	59.9	0.903	18.3	6.87	0.0675	2.33	1.10	1.24	3.15	0.168	94.0%

Table 3. Trace Element Composition

(Average of 3 runs)

Sample Name	V (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	Sr (ppm)	Nb (ppm)	Ba (ppm)	Y (ppm)	Co (ppm)	Sc (ppm)	Ga (ppm)	Ta (ppm)
						Sedimentary								
T05-54	126	53.4	23.33	76.6	91.4	7.39	131	15.4	46.7	28.2	12.2	13.8	15.3	7.24
T05-57A	136	101	27.30	45.4	38.6	14.4	271	3.72	105	10.7	11.9	16.8	14.6	6.28
T05-65	126	110	57.76	32.1	102	154	123	18.6	575	28.9	16.1	15.2	22.1	8.13
SC-1-FUSHAN	124	85.9	47.27	18.9	116	170	48.2	20.4	458	29.2	6.60	15.1	25.1	8.47
SC-2	121	84.6	45.87	18.9	112	164	48.8	20.7	447	31.5	9.65	14.8	24.4	8.73
SC-3	131	97.0	53.11	21.0	128	180	46.7	21.1	466	26.5	6.68	16.4	26.2	8.44
SAMPLE SITE R	42.9	40.4	10.26	4.72	36.8	114	30.9	8.97	571	11.8	3.32	5.50	8.85	6.69
WATERSHED	62.4	54.8	24.32	6.39	46.3	72.3	92.4	12.7	368	19.4	9.28	6.69	9.65	7.38
YYL STREAM #2	11.7	8.38	7.25	2.63	11.0	47.1	8.14	4.93	176	2.80	-0.424	0.853	3.91	6.92
SC-1	39.0	34.5	13.9	4.58	31.4	77.8	43.8	8.85	372	11.3	4.06	4.35	7.47	7.00
SC-5	37.7	32.6	15.2	4.53	29.6	65.7	48.1	8.81	305	11.2	4.30	3.97	7.01	7.10
						Igneous								
T05-22	265	247	109	46.1	80.7	3.94	190	3.62	36.2	33.1	41.3	36.5	15.3	8.51
T05-25	246	372	105	50.3	73.4	1.53	85.6	3.29	17.3	28.3	42.8	36.9	15.4	9.29
T05-53	191	311	116	57.8	64.5	7.42	135	3.40	98.6	21.9	32.9	30.3	14.2	7.87
T05-57B	200	103	47.0	36.5	55.4	24.8	186	3.74	126	14.0	22.9	31.2	17.4	7.66
T05-58	90.1	44.2	41.6	24.9	31.5	7.39	310	3.57	42.1	8.64	12.7	15.5	15.6	6.34
T05-59A	120	134	71.3	9.76	36.8	9.65	238	3.61	48.2	9.69	17.3	18.7	14.6	6.90
T05-59B	130	161	63.7	4.94	44.4	5.00	204	3.66	46.9	8.03	21.2	23.8	14.1	6.08
T05-59C	84.4	181	50.8	3.78	32.8	12.5	334	3.96	91.6	10.3	13.5	13.0	16.8	6.25
						Metamorphic								
SC-7	24.4	16.1	8.14	4.58	11.8	100	30.6	9.02	311	12.0	1.48	2.94	8.12	6.98
SC-10	14.7	42.3	5.10	0.69	2.89	64.2	22.1	6.39	211	7.12	0	0.966	5.01	6.25
ARGILLITE SCHIST	129	177	43.1	21.3	133	139	124	20.2	522	33.7	13.7	16.1	23.5	8.49
WULING PRISON	138	107	43.5	25.6	109	157	107	19.6	485	29.6	13.6	16.0	23.2	7.43

Discussion

The geochemistry of the rocks provides supporting evidence of the geologic history of the area along with a database to complement ongoing research. Overall elemental depletion of the rocks is evidence that the mountainous region of the Central Range was formed from the marine sediments originating from mainland China. The sediments had undergone a previous weathering cycle during their transport to the now existing Taiwan Strait. Therefore, if we sampled mainland China's watershed bedrock of relative ages we could possibly see a correlation as to the origin of Taiwan's Central Range. The lack of calcium in the rocks was consistent with the results in the Lanyang Hsi watershed of Carey et al. (2006).

The plot of the Na_20/Al_2O_3 vs. K_2O/Al_2O_3 led to a strong distinction between my igneous and sedimentary/metamorphic (originally sed.) rocks (Fig. 11). T05-54 and T05-57A fell in the igneous section of the two trends, even though both originally had been categorized as sedimentary. (T05-54 and T05-57A were left on spider plots with the other sedimentary rocks because they were originally identified as being sedimentary.) Figure 11, coupled with contradicting Rb and Ba trends compared to the sedimentary rocks, allowed for a definite rock name.

From the overall major oxide composition, it seems that YYL Stream #2 is more depleted, compared to its sedimentary counterparts. There is a definite similarity between SC-10 and YYL Stream #2. The difference in $\%K_2O$ and $\%Fe_2O_3$ could be attributed to differing weathering patterns or a rock of different origin.

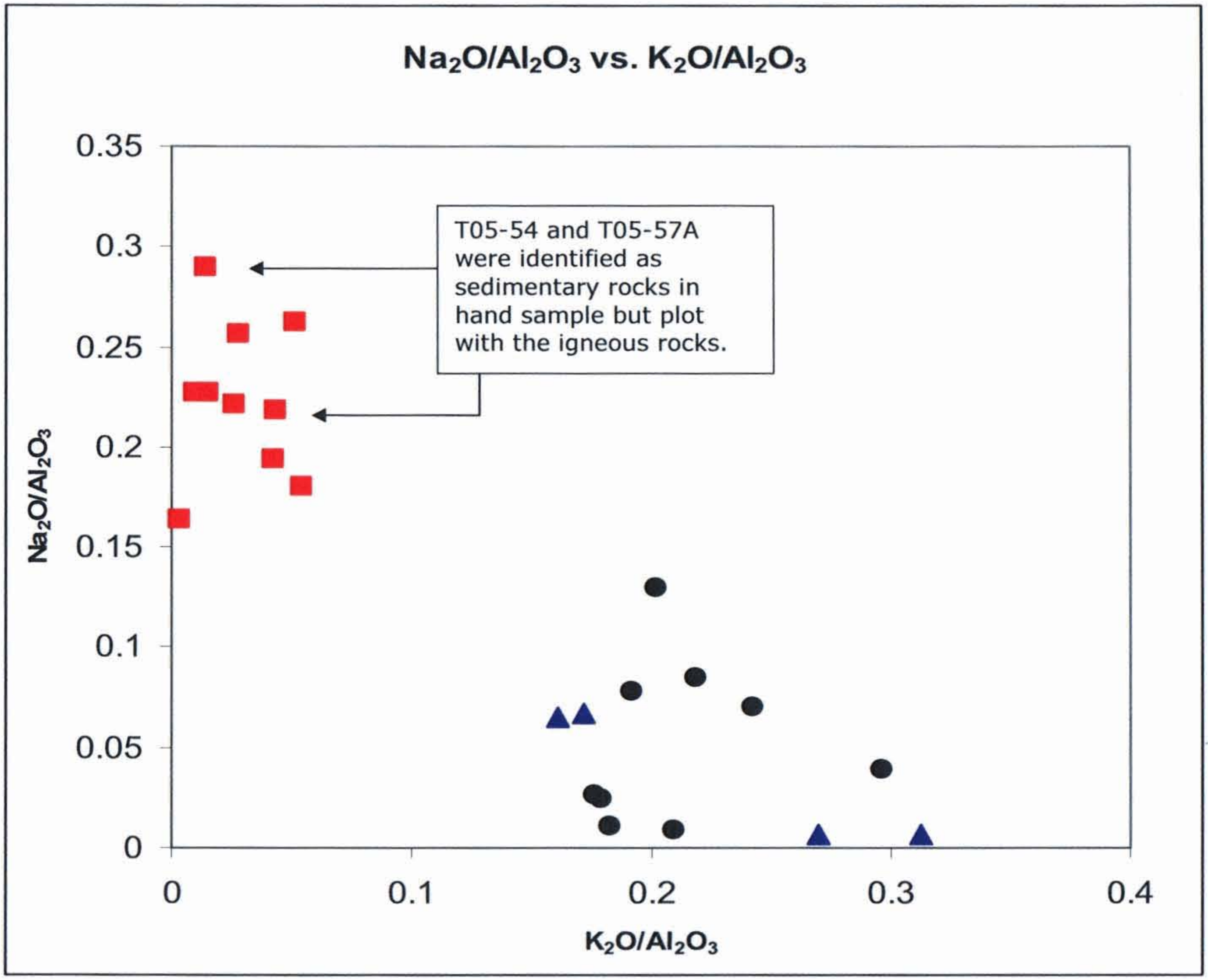

Fig. 11. Plot distinguishing certain ratio characteristic differences between igneous (red squares), sedimentary (black circles), and metamorphic (blue triangles) rocks.

Future field mapping should be done in the area in order to determine a better idea of the structure of the metamorphic complexes after the Penglai orogeny. Providing dates for the mafic igneous rocks collected would go a long way in helping to determine a more accurate timeline that produced the present-day structure.

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Standards For Application - Major Oxide Beads

USGS Standard BCR-2
Date Anaylized: 5/25/06

Element	Accuracy*	Precision**	LOD (mg/kg)
Al2O3	0.00%	0.09%	N/A
SiO2	0.41%	0.08%	N/A
Fe2O3	0.22%	0.07%	7.36
CaO	0.42%	0.06%	26.55
TiO2	0.00%	0.15%	10.93
MgO	0.28%	0.12%	21.77
MnO	N/A	0.00%	3.95
Na2O	0.95%	0.48%	31.35
K2O	0.00%	0.16%	8.76
P2O5	0.00%	0.83%	7.75

* Accuracy is presented difference from the accepted standard value

**Precision data is presented in the form of % relative standard deviation from three consecutive runs of the sample

Standards For Application - Trace Element Pressed Pellets

USGS Standard BCR-2
Date Anaylized: 5/26/06

Element	Accuracy*	Precision**	LOD (mg/kg)
Sc	3.0%	1.7%	1.414
V	0.45%	0.34%	2.3505
Cr	4.4%	0.9%	0.9795
Co	4.2%	0.6%	N/A
Ni	13%	0.6%	0.4915
Cu	21%	1.0%	0.4325
Zn	1.8%	0.2%	0.3485
Ga	4.1%	0.3%	0.5385
Rb	3.7%	0.5%	0.24
Sr	0.8%	0.3%	0.25
Y	3.9%	0.3%	0.406
Ba	12%	0.3%	N/A

USGS Standard BHVO-2
Date Anaylized: 5/26/06

Element	Accuracy*	Precison**	LOD (mg/kg)
Sc	16%	2.4%	1.487
V	1.6%	1.1%	2.551
Cr	3.3%	0.27%	1.001
Co	2.9%	0.34%	N/A
Ni	3.8%	0.62%	0.4935
Cu	4.4%	0.38%	0.4365
Zn	1.4%	0.27%	0.3545
Ga	6.9%	2.0%	0.5495
Rb	16%	0.76%	0.2455
Sr	2.3%	0.20%	0.257
Y	2.3%	0.26%	0.396
Ba	25%	0.38%	N/A

* Accuracy is presented difference from the accepted standard value

**Precision data is presented in the form of % relative standard deviation from three consecutive runs of the sample

Sample Name	Measurement date and time	Sum of conc. (%)	Result type	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)
GORDON-T05-22	4/28/2006 14:38	98.5538	Concentration	49.277	1.436	15.151	10.157	0.161	6.556	10.724	3.413	0.154	0.102
GORDON-T05-22	4/28/2006 14:27	98.3799	Concentration	49.104	1.433	15.038	10.132	0.159	6.533	10.713	3.417	0.152	0.102
GORDON-T05-22	4/28/2006 14:16	98.3271	Concentration	49.113	1.430	14.970	10.117	0.159	6.534	10.688	3.415	0.152	0.101
			Avg	**49.165**	**1.433**	**15.053**	**10.135**	**0.160**	**6.541**	**10.708**	**3.415**	**0.153**	**0.102**
			rel std dev	0.20%	0.22%	0.61%	0.20%	0.47%	0.20%	0.17%	0.06%	0.49%	0.54%
GORDON-T05-25	4/28/2006 11:37	97.1223	Concentration	47.334	1.224	14.935	9.491	0.142	7.629	10.988	2.447	0.051	0.085
GORDON-T05-25	4/28/2006 10:14	97.1481	Concentration	47.387	1.223	14.944	9.494	0.143	7.621	10.986	2.443	0.050	0.085
GORDON-T05-25	4/28/2006 8:51	97.1627	Concentration	47.403	1.222	14.931	9.493	0.143	7.636	11.001	2.443	0.050	0.086
			Avg	**47.375**	**1.223**	**14.937**	**9.493**	**0.142**	**7.629**	**10.992**	**2.444**	**0.050**	**0.085**
			rel std dev	0.08%	0.06%	0.05%	0.02%	0.41%	0.10%	0.07%	0.11%	1.10%	0.02%
GORDON-T05-53	4/28/2006 9:03	94.0285	Concentration	43.460	1.025	14.514	7.842	0.159	7.824	9.964	3.310	0.219	0.096
GORDON-T05-53	4/28/2006 11:49	93.9729	Concentration	43.417	1.024	14.503	7.835	0.158	7.806	9.955	3.295	0.220	0.096
GORDON-T05-53	4/28/2006 10:26	93.9092	Concentration	43.364	1.024	14.480	7.823	0.159	7.797	9.942	3.286	0.219	0.097
			Avg	**43.414**	**1.024**	**14.499**	**7.833**	**0.158**	**7.809**	**9.954**	**3.297**	**0.219**	**0.096**
			rel std dev	0.11%	0.06%	0.12%	0.13%	0.35%	0.17%	0.11%	0.37%	0.26%	0.51%
GORDON-T05-54	4/25/2006 14:09	96.95	Concentration	65.808	0.736	13.435	5.882	0.087	3.000	2.265	3.906	0.192	0.111
GORDON-T05-54	4/25/2006 12:30	96.95	Concentration	65.715	0.734	13.442	5.871	0.087	3.010	2.262	3.899	0.194	0.111
GORDON-T05-54	4/25/2006 10:42	96.95	Concentration	65.772	0.738	13.513	5.881	0.087	3.006	2.264	3.889	0.194	0.111
			Avg	**65.765**	**0.736**	**13.463**	**5.878**	**0.087**	**3.005**	**2.263**	**3.898**	**0.193**	**0.111**
			rel std dev	0.07%	0.26%	0.32%	0.10%	0.00%	0.18%	0.07%	0.23%	0.58%	0.50%
GORDON-T05-57A	5/4/2006 13:46	98.36	Concentration	64.698	0.402	15.969	4.142	0.075	2.928	5.999	3.490	0.694	0.108
GORDON-T05-57A	5/4/2006 12:58	98.36	Concentration	64.656	0.398	15.977	4.139	0.076	2.925	5.997	3.483	0.693	0.107
GORDON-T05-57A	5/4/2006 12:10	98.36	Concentration	64.549	0.401	15.955	4.136	0.076	2.934	5.995	3.481	0.694	0.108
			Avg	**64.634**	**0.401**	**15.967**	**4.139**	**0.075**	**2.929**	**5.997**	**3.485**	**0.694**	**0.108**
			rel std dev	0.12%	0.51%	0.07%	0.07%	0.75%	0.15%	0.03%	0.13%	0.08%	0.53%
GORDON-T05-57B	4/26/2006 4:17	99.4705	Concentration	55.350	0.501	17.777	6.781	0.128	5.506	8.635	3.197	0.976	0.093
GORDON-T05-57B	4/25/2006 21:47	99.3499	Concentration	55.203	0.499	17.741	6.768	0.129	5.497	8.605	3.195	0.975	0.093
GORDON-T05-57B	4/25/2006 15:16	99.2412	Concentration	55.137	0.499	17.654	6.750	0.128	5.477	8.579	3.194	0.975	0.093
			Avg	**55.230**	**0.500**	**17.724**	**6.766**	**0.128**	**5.493**	**8.606**	**3.195**	**0.975**	**0.093**
			rel std dev	0.20%	0.28%	0.36%	0.23%	0.46%	0.27%	0.32%	0.05%	0.07%	0.52%
GORDON-T05-58	4/25/2006 10:53	97.747	Concentration	62.231	0.353	16.619	3.250	0.041	2.598	5.662	4.244	0.465	0.082
GORDON-T05-58	4/25/2006 14:21	97.8485	Concentration	62.391	0.354	16.597	3.254	0.041	2.609	5.679	4.269	0.470	0.080
GORDON-T05-58	4/25/2006 12:42	97.7362	Concentration	62.235	0.352	16.557	3.253	0.040	2.603	5.677	4.256	0.469	0.081
			Avg	**62.286**	**0.353**	**16.591**	**3.252**	**0.041**	**2.603**	**5.672**	**4.257**	**0.468**	**0.081**
			rel std dev	0.15%	0.34%	0.19%	0.07%	1.42%	0.20%	0.17%	0.29%	0.51%	1.15%
GORDON-T05-59A	4/25/2006 14:33	97.8721	Concentration	59.520	0.421	16.627	4.199	0.058	4.251	6.678	3.234	0.718	0.084
GORDON-T05-59A	4/25/2006 12:54	98.0641	Concentration	59.851	0.421	16.640	4.204	0.057	4.263	6.696	3.232	0.720	0.083
GORDON-T05-59A	4/25/2006 11:05	97.9098	Concentration	59.579	0.421	16.653	4.197	0.057	4.248	6.668	3.234	0.721	0.085
			Avg	**59.650**	**0.421**	**16.640**	**4.200**	**0.057**	**4.254**	**6.680**	**3.233**	**0.720**	**0.084**
			rel std dev	0.30%	0.04%	0.08%	0.08%	0.92%	0.18%	0.21%	0.03%	0.16%	1.09%
GORDON-T05-59B	4/26/2006 4:29	98.6163	Concentration	58.713	0.371	16.677	4.914	0.087	5.526	6.740	3.685	0.447	0.091
GORDON-T05-59B	4/25/2006 21:58	98.6958	Concentration	58.885	0.370	16.655	4.920	0.087	5.529	6.748	3.678	0.447	0.089
GORDON-T05-59B	4/25/2006 15:28	98.7036	Concentration	58.856	0.370	16.694	4.918	0.087	5.519	6.743	3.697	0.447	0.091
			Avg	**58.818**	**0.370**	**16.675**	**4.917**	**0.087**	**5.525**	**6.744**	**3.687**	**0.447**	**0.090**
			rel std dev	0.16%	0.11%	0.12%	0.06%	0.05%	0.10%	0.06%	0.26%	0.05%	1.24%
GORDON-T05-59C	4/26/2006 4:41	99.571	Concentration	64.620	0.401	16.845	3.706	0.029	2.477	5.636	4.418	0.869	0.143
GORDON-T05-59C	4/25/2006 22:10	99.3657	Concentration	64.308	0.402	16.798	3.694	0.030	2.467	5.624	4.404	0.864	0.143
GORDON-T05-59C	4/25/2006 15:39	99.3764	Concentration	64.272	0.399	16.838	3.695	0.030	2.467	5.624	4.419	0.868	0.145
			Avg	**64.400**	**0.401**	**16.827**	**3.698**	**0.029**	**2.470**	**5.628**	**4.414**	**0.867**	**0.144**
			rel std dev	0.30%	0.37%	0.15%	0.18%	1.83%	0.24%	0.12%	0.19%	0.28%	0.75%
GORDON-T05-65	4/28/2006 10:38	94.56	Concentration	59.654	0.843	17.556	6.330	0.070	2.648	1.847	1.374	3.386	0.140
GORDON-T05-65	4/28/2006 12:01	94.56	Concentration	59.654	0.845	17.605	6.331	0.070	2.650	1.848	1.377	3.381	0.140
GORDON-T05-65	4/28/2006 9:15	94.56	Concentration	59.689	0.843	17.579	6.326	0.070	2.642	1.847	1.374	3.382	0.141
			Avg	**59.666**	**0.844**	**17.580**	**6.329**	**0.070**	**2.646**	**1.847**	**1.375**	**3.383**	**0.140**
			rel std dev	0.03%	0.13%	0.14%	0.04%	0.00%	0.15%	0.03%	0.12%	0.07%	0.39%
GORDON-SC-1	4/28/2006 11:13	95.15	Concentration	54.336	0.854	21.242	6.680	0.016	2.337	0.000	0.383	3.968	0.097
GORDON-SC-1	4/28/2006 9:50	95.15	Concentration	54.298	0.855	21.344	6.682	0.017	2.327	0.000	0.381	3.967	0.097
GORDON-SC1	4/28/2006 8:27	95.15	Concentration	54.277	0.855	21.242	6.685	0.017	2.323	0.000	0.378	3.976	0.096
			Avg	**54.304**	**0.854**	**21.276**	**6.682**	**0.017**	**2.329**	**0.000**	**0.381**	**3.970**	**0.096**
			rel std dev	0.05%	0.06%	0.28%	0.04%	3.27%	0.32%	#DIV/0!	0.76%	0.13%	0.57%
GORDON-SC-1-FUSHAN	4/28/2006 11:25	95.12	Concentration	59.566	0.851	19.761	7.559	0.022	2.499	0.000	0.488	3.542	0.117
GORDON-SC-1-FUSHAN	4/28/2006 10:02	95.12	Concentration	59.632	0.851	19.736	7.561	0.021	2.497	0.000	0.484	3.544	0.118
GORDON-SC1-FUSHAN	4/28/2006 8:39	95.12	Concentration	59.845	0.851	19.803	7.565	0.022	2.492	0.000	0.488	3.545	0.117
			Avg	**59.681**	**0.851**	**19.767**	**7.562**	**0.022**	**2.496**	**0.000**	**0.487**	**3.544**	**0.117**
			rel std dev	0.24%	0.00%	0.17%	0.04%	2.55%	0.14%	#DIV/0!	0.45%	0.04%	0.47%
GORDON-SC-2	4/25/2006 13:22	95.28	Concentration	59.427	0.869	19.496	7.535	0.027	2.542	0.000	0.513	3.442	0.117
GORDON-SC-2	4/25/2006 11:43	95.28	Concentration	59.676	0.869	19.465	7.539	0.027	2.543	0.000	0.516	3.448	0.117
GORDON-SC-2	4/25/2006 9:54	95.28	Concentration	59.594	0.866	19.448	7.526	0.027	2.533	0.000	0.511	3.435	0.116
			Avg	**59.566**	**0.868**	**19.470**	**7.533**	**0.027**	**2.540**	**0.000**	**0.513**	**3.442**	**0.117**
			rel std dev	0.21%	0.19%	0.13%	0.08%	0.00%	0.21%	#DIV/0!	0.57%	0.19%	0.47%

Sample Name	Measurement date and time	Sum of conc. (%)	Result type	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)
GORDON-SC-3	4/25/2006 13:33	94.92	Concentration	56.550	0.890	20.742	7.799	0.022	2.401	0.000	0.218	3.797	0.090
GORDON-SC-3	4/25/2006 11:55	94.92	Concentration	56.681	0.894	20.745	7.801	0.022	2.401	0.000	0.217	3.797	0.090
GORDON-SC-3	4/25/2006 10:06	94.92	Concentration	56.547	0.889	20.719	7.785	0.021	2.400	0.000	0.216	3.786	0.088
			Avg	**56.593**	**0.891**	**20.735**	**7.795**	**0.022**	**2.401**	**0.000**	**0.217**	**3.793**	**0.090**
			rel std dev	0.13%	0.28%	0.07%	0.11%	2.55%	0.04%	#DIV/0!	0.44%	0.16%	1.22%
GORDON-SC-5	4/25/2006 13:33	94.78	Concentration	56.687	0.876	21.213	8.426	0.039	2.743	0.000	0.222	3.753	0.079
GORDON-SC-5	4/25/2006 11:55	94.78	Concentration	56.565	0.874	21.207	8.417	0.038	2.745	0.000	0.224	3.755	0.081
GORDON-SC-5	4/25/2006 10:06	94.78	Concentration	56.587	0.877	21.175	8.413	0.038	2.745	0.000	0.224	3.748	0.080
			Avg	**56.613**	**0.875**	**21.198**	**8.419**	**0.038**	**2.744**	**0.000**	**0.223**	**3.752**	**0.080**
			rel std dev	0.12%	0.17%	0.10%	0.08%	1.43%	0.04%	#DIV/0!	0.49%	0.11%	1.19%
GORDON-SC-7	4/25/2006 13:45	97.4185	Concentration	84.334	0.213	7.627	0.469	0.004	0.169	0.000	0.049	2.057	0.033
GORDON-SC-7	4/25/2006 12:07	97.3074	Concentration	84.131	0.212	7.618	0.468	0.004	0.167	0.000	0.051	2.054	0.034
GORDON-SC-7	4/25/2006 10:18	97.1782	Concentration	83.909	0.213	7.593	0.466	0.004	0.169	0.000	0.053	2.048	0.033
			Avg	**84.125**	**0.213**	**7.613**	**0.468**	**0.004**	**0.168**	**0.000**	**0.051**	**2.053**	**0.033**
			rel std dev	0.25%	0.29%	0.23%	0.24%	0.12%	0.52%	#DIV/0!	4.68%	0.23%	1.69%
GORDON-SC-10	4/25/2006 13:57	98.2567	Concentration	89.561	0.109	4.917	0.315	0.004	0.105	0.000	0.034	1.532	0.019
GORDON-SC-10	4/25/2006 12:19	98.2482	Concentration	89.552	0.110	4.907	0.315	0.004	0.106	0.000	0.033	1.534	0.020
GORDON-SC-10	4/25/2006 10:30	98.3608	Concentration	89.766	0.109	4.912	0.317	0.003	0.103	0.000	0.035	1.536	0.019
			Avg	**89.626**	**0.109**	**4.912**	**0.316**	**0.004**	**0.105**	**0.000**	**0.034**	**1.534**	**0.019**
			rel std dev	0.13%	0.49%	0.10%	0.24%	15.69%	1.37%	#DIV/0!	2.91%	0.15%	2.95%
GORDON-SAMPLE SITE R	4/28/2006 13:28	98.02	Concentration	80.337	0.327	9.964	2.786	0.078	0.215	0.000	0.385	2.952	0.078
GORDON-SAMPLE SITE R	4/28/2006 13:04	98.02	Concentration	80.361	0.326	9.998	2.788	0.078	0.216	0.000	0.387	2.953	0.079
GORDON-SAMPLE SITE R	4/28/2006 12:40	98.02	Concentration	80.375	0.328	9.980	2.785	0.078	0.219	0.000	0.386	2.953	0.078
			Avg	**80.358**	**0.327**	**9.981**	**2.786**	**0.078**	**0.216**	**0.000**	**0.386**	**2.953**	**0.079**
			rel std dev	0.02%	0.30%	0.17%	0.05%	0.00%	0.94%	#DIV/0!	0.25%	0.02%	0.72%
GORDON-WATERSHED	4/28/2006 13:40	98.01	Concentration	79.291	0.563	9.632	3.269	0.081	0.883	0.295	1.251	1.950	0.091
GORDON-WATERSHED	4/28/2006 13:16	98.01	Concentration	79.211	0.564	9.613	3.267	0.081	0.886	0.295	1.254	1.948	0.092
GORDON-WATERSHED	4/28/2006 12:52	98.01	Concentration	79.272	0.560	9.651	3.262	0.081	0.879	0.294	1.254	1.951	0.091
			Avg	**79.258**	**0.562**	**9.632**	**3.266**	**0.081**	**0.883**	**0.295**	**1.253**	**1.950**	**0.091**
			rel std dev	0.05%	0.36%	0.20%	0.11%	0.00%	0.39%	0.19%	0.14%	0.08%	0.62%
GORDON-YYL STREAM #2	4/28/2006 12:25	99.28	Concentration	92.306	0.070	4.249	0.530	0.006	0.127	0.000	0.038	0.890	0.014
GORDON-YYL STREAM #2	4/28/2006 11:02	99.28	Concentration	92.197	0.069	4.268	0.529	0.007	0.127	0.000	0.039	0.890	0.014
GORDON-YYL STREAM #2	4/28/2006 9:38	99.28	Concentration	92.252	0.070	4.227	0.531	0.007	0.126	0.000	0.040	0.890	0.013
			Avg	**92.252**	**0.070**	**4.248**	**0.530**	**0.007**	**0.127**	**0.000**	**0.039**	**0.890**	**0.014**
			rel std dev	0.06%	0.82%	0.48%	0.19%	8.66%	0.45%	#DIV/0!	2.56%	0.00%	4.22%
GORDON-ARGILLITE SCH	4/28/2006 12:13	95	Concentration	59.950	0.887	17.716	8.034	0.087	2.727	0.777	1.157	2.863	0.171
GORDON-ARGILLITE SCH	4/28/2006 10:50	95	Concentration	59.896	0.887	17.710	8.030	0.087	2.727	0.776	1.161	2.860	0.174
GORDON-ARGILLITE SCH	4/28/2006 9:26	95	Concentration	59.923	0.884	17.739	8.036	0.087	2.723	0.781	1.159	2.867	0.172
			Avg	**59.923**	**0.886**	**17.722**	**8.034**	**0.087**	**2.726**	**0.778**	**1.159**	**2.863**	**0.172**
			rel std dev	0.05%	0.19%	0.09%	0.04%	0.00%	0.10%	0.32%	0.16%	0.13%	0.84%
GORDON-WULING PRISON	4/26/2006 4:53	95.01	Concentration	59.937	0.904	18.300	6.868	0.067	2.327	1.095	1.239	3.150	0.168
GORDON-WULING PRISON	4/25/2006 22:22	95.01	Concentration	59.813	0.901	18.284	6.863	0.067	2.328	1.095	1.240	3.144	0.168
GORDON-WULING PRISON	4/25/2006 15:51	95.01	Concentration	59.997	0.904	18.311	6.872	0.067	2.329	1.097	1.235	3.153	0.168
			Avg	**59.916**	**0.903**	**18.298**	**6.868**	**0.067**	**2.328**	**1.095**	**1.238**	**3.149**	**0.168**
			rel std dev	0.16%	0.18%	0.08%	0.07%	0.00%	0.04%	0.15%	0.20%	0.15%	0.00%

Sample Name	Measurement date and time	V (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	Sr (ppm)	Nb (ppm)	Ba (ppm)	Y (ppm)	Co (ppm)	Sc (ppm)	Ga (ppm)
GORDON-T05-22	4/27/2006 12:10	264.888	247.17	109.168	46.037	81.081	3.941	189.921	3.662	35.415	33.064	41.573	36.422	15.409
GORDON-T05-22	4/28/2006 1:31	265.314	248.389	109.555	46.128	80.695	3.981	189.992	3.621	34.457	33.277	41.482	37.243	15.058
GORDON-T05-22	4/26/2006 22:50	264.649	244.298	109.19	46.103	80.26	3.91	189.089	3.573	38.72	33.059	40.841	35.816	15.311
	avg	**265**	**247**	**109**	**46**	**81**	**4**	**190**	**4**	**36**	**33**	**41**	**36**	**15**
	rel std dev	**0.13%**	**0.85%**	**0.20%**	**0.10%**	**0.51%**	**0.90%**	**0.26%**	**1.23%**	**6.18%**	**0.38%**	**0.97%**	**1.96%**	**1.19%**
GORDON-T05-25	4/29/2006 4:27	246.594	371.818	104.762	50.024	73.435	1.784	85.673	3.144	20.029	28.153	42.27	36.568	15.474
GORDON-T05-25	4/29/2006 17:48	247.851	373.041	105.471	50.205	73.671	1.566	85.931	3.357	14.072	28.46	42.556	36.439	15.675
GORDON-T05-25	4/28/2006 15:06	244.985	369.885	104.828	50.676	73.08	1.229	85.133	3.378	17.924	28.327	43.426	37.605	15.146
	avg	**246**	**372**	**105**	**50**	**73**	**1.53**	**86**	**3**	**17**	**28**	**43**	**37**	**15**
	rel std dev	**0.58%**	**0.43%**	**0.37%**	**0.67%**	**0.41%**	**18.32%**	**0.48%**	**3.93%**	**17.42%**	**0.54%**	**1.41%**	**1.73%**	**1.73%**
GORDON-T05-53	4/29/2006 19:42	191.724	312.944	116.542	57.92	64.864	7.515	135.793	3.444	94.273	21.856	32.976	30.27	14.289
GORDON-T05-53	4/29/2006 6:22	191.259	310.526	116.056	57.928	64.176	7.515	135.667	3.481	100.895	21.901	32.95	31.191	14.313
GORDON-T05-53	4/28/2006 17:01	189.604	309.159	116.155	57.581	64.482	7.223	134.822	3.277	100.636	21.855	32.819	29.337	14.113
	avg	**191**	**311**	**116**	**58**	**65**	**7**	**135**	**3**	**99**	**22**	**33**	**30**	**14**
	rel std dev	**0.58%**	**0.62%**	**0.22%**	**0.34%**	**0.53%**	**2.27%**	**0.39%**	**3.20%**	**3.80%**	**0.12%**	**0.26%**	**3.06%**	**0.77%**
GORDON-T05-54	4/29/2006 21:37	125.346	53.716	23.277	76.959	91.512	7.413	131.194	15.515	46.332	28.218	12.582	13.115	15.251
GORDON-T05-54	4/29/2006 8:16	126.66	53.108	23.219	76.729	91.251	7.375	130.628	15.412	47.509	28.232	11.974	14.076	15.42
GORDON-T05-54	4/28/2006 18:55	125.127	53.478	23.489	76.165	91.307	7.392	130.361	15.39	46.225	28.031	12.054	14.243	15.15
	avg	**126**	**53**	**23**	**77**	**91**	**7**	**131**	**15**	**47**	**28**	**12**	**14**	**15**
	rel std dev	**0.66%**	**0.57%**	**0.61%**	**0.53%**	**0.15%**	**0.26%**	**0.33%**	**0.43%**	**1.53%**	**0.40%**	**2.71%**	**4.41%**	**0.89%**
GORDON-T05-57A	5/2/2006 9:42	135.624	101.389	27.235	45.376	38.421	14.667	272.232	3.73	107.469	10.804	11.714	17.111	14.699
GORDON-T05-57A	5/1/2006 22:15	135.335	101.725	27.339	45.538	38.803	14.378	271.416	3.596	105.883	10.79	12.225	17.025	14.639
GORDON-T05-57A	5/1/2006 10:48	135.654	100.16	27.318	45.253	38.435	14.215	269.947	3.819	102.987	10.569	11.634	16.259	14.445
	avg	**136**	**101**	**27**	**45**	**39**	**14**	**271**	**4**	**105**	**11**	**12**	**17**	**15**
	rel std dev	**0.13%**	**0.81%**	**0.20%**	**0.31%**	**0.56%**	**1.59%**	**0.43%**	**3.02%**	**2.16%**	**1.23%**	**2.70%**	**2.79%**	**0.91%**
GORDON-T05-57B	4/28/2006 3:26	200.931	103.56	47.476	36.664	55.594	24.963	186.868	3.804	127.454	13.983	22.973	31.324	17.37
GORDON-T05-57B	4/27/2006 14:05	199.41	103.061	46.664	36.263	55.58	24.752	186.37	3.826	125.536	13.976	22.175	31.373	17.315
GORDON-T05-57B	4/27/2006 0:44	199.394	101.446	46.97	36.449	54.936	24.56	185.54	3.603	123.643	14.041	23.411	30.872	17.399
	avg	**200**	**103**	**47**	**36**	**55**	**25**	**186**	**4**	**126**	**14**	**23**	**31**	**17**
	rel std dev	**0.44%**	**1.08%**	**0.87%**	**0.55%**	**0.68%**	**0.81%**	**0.36%**	**3.28%**	**1.52%**	**0.25%**	**2.74%**	**0.89%**	**0.25%**
GORDON-T05-58	4/29/2006 23:31	90.381	44.236	41.88	25.288	31.695	7.424	310.57	3.5	42.851	8.622	12.734	14.704	15.707
GORDON-T05-58	4/29/2006 10:10	89.684	44.807	41.651	24.743	31.52	7.471	310.15	3.604	39.765	8.625	12.745	16.046	15.688
GORDON-T05-58	4/28/2006 20:49	90.191	43.428	41.327	24.741	31.329	7.266	308.91	3.599	43.577	8.683	12.675	15.635	15.439
	avg	**90**	**44**	**42**	**25**	**32**	**7**	**310**	**4**	**42**	**9**	**13**	**15**	**16**
	rel std dev	**0.40%**	**1.57%**	**0.67%**	**1.26%**	**0.58%**	**1.45%**	**0.28%**	**1.64%**	**4.81%**	**0.40%**	**0.30%**	**4.45%**	**0.96%**
GORDON-T05-59A	4/30/2006 1:26	119.811	135.181	71.359	9.348	36.933	9.553	238.39	3.59	49.356	9.809	17.379	18.267	14.803
GORDON-T05-59A	4/29/2006 12:05	121.711	133.645	71.483	10.071	36.766	9.679	237.895	3.624	47.642	9.736	17.626	18.962	14.442
GORDON-T05-59A	4/28/2006 22:44	118.17	133.832	71.193	9.865	36.723	9.729	237.297	3.607	47.675	9.531	16.862	18.978	14.648
	avg	**120**	**134**	**71**	**10**	**37**	**10**	**238**	**4**	**48**	**10**	**17**	**19**	**15**
	rel std dev	**1.48%**	**0.62%**	**0.20%**	**3.82%**	**0.30%**	**0.94%**	**0.23%**	**0.47%**	**2.03%**	**1.49%**	**2.26%**	**2.17%**	**1.24%**
GORDON-T05-59B	4/30/2006 3:20	130.304	161.345	63.986	5.027	44.682	5.042	204.827	3.632	47.316	8.102	21.627	23.285	14.233
GORDON-T05-59B	4/29/2006 13:59	131.022	161.009	63.368	4.803	44.42	4.957	204.533	3.744	47.89	8.154	20.859	25.037	14.13
GORDON-T05-59B	4/29/2006 0:38	129.276	160.642	63.652	4.978	44.133	5.013	203.512	3.599	45.623	7.848	21.163	23.155	14.046
	avg	**130**	**161**	**64**	**5**	**44**	**5**	**204**	**4**	**47**	**8**	**21**	**24**	**14**
	rel std dev	**0.67%**	**0.22%**	**0.49%**	**2.39%**	**0.62%**	**0.86%**	**0.34%**	**2.08%**	**2.51%**	**2.04%**	**1.82%**	**4.41%**	**0.66%**
GORDON-T05-59C	4/30/2006 5:15	84.778	181.753	51.183	3.894	32.991	12.507	335.299	3.991	91.356	10.175	13.709	13.191	17.015
GORDON-T05-59C	4/29/2006 15:54	84.15	180.417	50.838	4.023	32.789	12.492	334.954	4.029	93.259	10.424	13.489	13.135	16.84
GORDON-T05-59C	4/29/2006 2:33	84.157	180.929	50.498	3.428	32.587	12.422	333.197	3.86	90.246	10.23	13.154	12.538	16.644
	avg	**84**	**181**	**51**	**4**	**33**	**12**	**334**	**4**	**92**	**10**	**13**	**13**	**17**
	rel std dev	**0.43%**	**0.37%**	**0.67%**	**8.28%**	**0.62%**	**0.36%**	**0.34%**	**2.24%**	**1.66%**	**1.27%**	**2.08%**	**2.79%**	**1.10%**
GORDON-T05-65	4/28/2006 5:20	126.234	109.805	58.211	31.99	102.282	154.426	123.308	18.5	574.952	28.927	16.348	14.984	22.242
GORDON-T05-65	4/27/2006 15:59	126.805	110.265	57.749	32.194	102.255	153.947	123.109	18.697	576.912	29.013	15.543	14.709	21.819
GORDON-T05-65	4/27/2006 2:38	126.037	109.04	57.327	32.14	102.004	153.599	122.756	18.605	572.312	28.627	16.346	15.978	22.133
	avg	**126**	**110**	**58**	**32**	**102**	**154**	**123**	**19**	**575**	**29**	**16**	**15**	**22**
	rel std dev	**0.32%**	**0.56%**	**0.77%**	**0.33%**	**0.15%**	**0.27%**	**0.23%**	**0.53%**	**0.40%**	**0.70%**	**2.89%**	**4.39%**	**1.00%**
GORDON-SC-1	4/26/2006 7:00	138.16	93.16	44.111	18.69	90.158	202.2	47.899	21.918	530.173	27.593	5.675	17.223	27.561
GORDON-SC-1	4/26/2006 0:29	135.505	93.144	44.716	18.534	89.537	201.494	47.607	21.885	527.158	27.324	5.281	16.718	27.187
GORDON-SC-1	4/25/2006 17:58	135.006	93.969	44.494	18.426	88.806	200.646	47.43	21.787	526.354	27.492	5.781	16.847	27.313
	avg	**136**	**93**	**44**	**19**	**90**	**201**	**48**	**22**	**528**	**27**	**6**	**17**	**27**
	rel std dev	**1.24%**	**0.50%**	**0.69%**	**0.72%**	**0.76%**	**0.39%**	**0.50%**	**0.31%**	**0.38%**	**0.49%**	**4.72%**	**1.55%**	**0.70%**

Sample Name	Measurement date and time	V (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	Sr (ppm)	Nb (ppm)	Ba (ppm)	Y (ppm)	Co (ppm)	Sc (ppm)	Ga (ppm)
GORDON-SC-1-FUSHAN	4/26/2006 5:05	125.772	86.307	47.542	19.106	117.032	170.18	48.482	20.354	461.519	29.402	6.862	15.55	25.323
GORDON-SC-1-FUSHAN	4/25/2006 22:34	124.469	85.819	47.241	18.914	116.269	169.992	48.328	20.374	458.465	29.013	6.134	15.376	24.887
GORDON-SC-1-FUSHAN	4/25/2006 16:03	122.73	85.518	47.032	18.708	115.918	169.183	47.911	20.347	452.943	29.138	6.789	14.477	25.106
	avg	**124**	**86**	**47**	**19**	**116**	**170**	**48**	**20**	**458**	**29**	**7**	**15**	**25**
	rel std dev	**1.23%**	**0.46%**	**0.54%**	**1.05%**	**0.49%**	**0.31%**	**0.61%**	**0.07%**	**0.95%**	**0.68%**	**6.08%**	**3.81%**	**0.87%**
GORDON-SC-2	4/26/2006 8:54	122.34	85.161	46.218	19.401	112.149	164.375	49.088	20.824	448.642	31.684	9.256	15.099	24.351
GORDON-SC-2	4/26/2006 2:23	119.611	84.739	45.846	18.642	112.124	164.38	48.862	20.798	445.755	31.498	9.768	15.342	24.732
GORDON-SC-2	4/25/2006 19:52	119.958	83.818	45.555	18.665	111.543	163.682	48.412	20.606	445.697	31.381	9.93	13.811	24.201
	avg	**121**	**85**	**46**	**19**	**112**	**164**	**49**	**21**	**447**	**32**	**10**	**15**	**24**
	rel std dev	**1.23%**	**0.81%**	**0.72%**	**2.28%**	**0.31%**	**0.24%**	**0.71%**	**0.57%**	**0.38%**	**0.48%**	**3.65%**	**5.58%**	**1.12%**
GORDON-SC-3	4/27/2006 17:54	133.234	97.644	53.304	21.212	128.578	180.121	46.738	21.103	470.174	26.439	6.733	16.124	26.37
GORDON-SC-3	4/27/2006 4:33	130.869	96.752	53.144	20.888	128.191	179.884	46.803	21.253	466.517	26.542	6.6	16.759	26.258
GORDON-SC-3	4/26/2006 15:12	129.937	96.678	52.891	20.836	127.977	178.835	46.543	20.921	460.527	26.433	6.695	16.374	25.838
	avg	**131**	**97**	**53**	**21**	**128**	**180**	**47**	**21**	**466**	**26**	**7**	**16**	**26**
	rel std dev	**1.29%**	**0.55%**	**0.39%**	**0.97%**	**0.24%**	**0.38%**	**0.29%**	**0.79%**	**1.05%**	**0.23%**	**1.03%**	**1.95%**	**1.07%**
GORDON-SC-5	4/27/2006 19:48	137.121	92.261	65.613	27.411	135.323	181.446	47.859	21.035	510.47	27.947	15.26	16.219	27.72
GORDON-SC-5	4/27/2006 6:27	136.779	92.67	65.111	27.435	135.46	181.045	47.641	20.768	506.538	28.154	14.313	15.342	27.51
GORDON-SC-5	4/26/2006 17:06	137.553	92.662	65.16	27.438	134.439	179.902	47.394	20.978	505.539	27.826	14.911	15.908	27.121
	avg	**137**	**93**	**65**	**27**	**135**	**181**	**48**	**21**	**508**	**28**	**15**	**16**	**27**
	rel std dev	**0.28%**	**0.25%**	**0.42%**	**0.05%**	**0.41%**	**0.44%**	**0.49%**	**0.67%**	**0.51%**	**0.59%**	**3.23%**	**2.81%**	**1.11%**
GORDON-SC-7	4/27/2006 21:43	23.83	15.912	8.094	4.829	11.707	99.995	30.716	8.951	312.351	12.202	1.39	2.947	8.183
GORDON-SC-7	4/27/2006 8:22	24.742	16.351	8.191	4.341	11.892	99.917	30.529	9.148	314.53	11.896	1.897	3.006	8.195
GORDON-SC-7	4/26/2006 19:01	24.562	15.915	8.149	4.565	11.679	99.463	30.451	8.956	307.168	11.977	1.167	2.866	7.968
	avg	**24**	**16**	**8**	**5**	**12**	**100**	**31**	**9**	**311**	**12**	**1**	**3**	**8**
	rel std dev	**1.98%**	**1.57%**	**0.60%**	**5.34%**	**0.98%**	**0.29%**	**0.45%**	**1.25%**	**1.21%**	**1.32%**	**25.20%**	**2.39%**	**1.57%**
GORDON-SC-10	4/27/2006 23:37	15.194	42.379	5.21	0.672	2.938	64.335	22.122	6.365	210.734	7.145	0	0.998	5.061
GORDON-SC-10	4/27/2006 10:16	14.373	42.369	5.356	0.71	2.881	64.218	22.068	6.437	211.626	7.128	0	1.302	4.847
GORDON-SC-10	4/26/2006 20:55	14.657	42.119	4.747	0.678	2.865	64.172	22.06	6.359	211.115	7.1	0	0.597	5.129
	avg	**15**	**42**	**5**	**1**	**3**	**64**	**22**	**6**	**211**	**7**	**0**	**1**	**5**
	rel std dev	**2.83%**	**0.35%**	**6.23%**	**2.98%**	**1.33%**	**0.13%**	**0.15%**	**0.68%**	**0.21%**	**0.32%**	**0.00%**	**36.62%**	**2.94%**
GORDON-SAMPLE SITE F	5/3/2006 23:42	42.585	40.395	10.276	4.655	36.694	113.915	30.804	8.895	572.424	11.878	3.498	5.237	8.843
GORDON-SAMPLE SITE F	5/1/2006 12:43	42.719	39.76	10.19	4.641	36.909	114.045	30.997	8.899	568.943	11.692	3.034	5.529	8.635
GORDON-SAMPLE SITE F	5/2/2006 0:09	43.254	40.975	10.318	4.868	36.916	114.117	30.904	9.123	573.053	11.81	3.414	5.728	9.078
	avg	**43**	**40**	**10**	**5**	**37**	**114**	**31**	**9**	**571**	**12**	**3**	**5**	**9**
	rel std dev	**0.83%**	**1.51%**	**0.64%**	**2.69%**	**0.34%**	**0.09%**	**0.31%**	**1.45%**	**0.39%**	**0.80%**	**7.46%**	**4.49%**	**2.50%**
GORDON-WATERSHED	5/3/2006 16:04	62.777	55.575	24.524	5.465	46.146	72.401	92.46	12.538	366.565	19.532	9.473	6.149	9.795
GORDON-WATERSHED	5/2/2006 7:47	62.8	55.247	24.519	5.461	46.296	72.25	92.19	12.713	366.685	19.389	9.41	6.751	9.69
GORDON-WATERSHED	5/1/2006 20:21	61.623	53.615	23.902	8.236	46.606	72.231	92.68	12.717	370.105	19.357	8.949	7.184	9.457
	avg	**62**	**55**	**24**	**6**	**46**	**72**	**92**	**13**	**368**	**19**	**9**	**7**	**10**
	rel std dev	**1.08%**	**1.92%**	**1.47%**	**25.07%**	**0.51%**	**0.13%**	**0.27%**	**0.81%**	**0.55%**	**0.48%**	**3.08%**	**7.76%**	**1.79%**
GORDON-YYL STREAM #:	5/3/2006 17:59	11.953	7.731	7.235	2.589	11.165	47.136	8.085	4.983	177.762	2.712	0	0.812	4.033
GORDON-YYL STREAM #:	5/2/2006 5:53	11.889	8.267	7.239	2.585	10.927	47.318	8.275	4.895	176.049	2.957	0	0.34	3.939
GORDON-YYL STREAM #:	5/1/2006 18:26	11.198	9.147	7.282	2.714	11.011	46.923	8.053	4.924	174.939	2.716	0	1.406	3.769
	avg	**12**	**8**	**7**	**3**	**11**	**47**	**8**	**5**	**176**	**3**	**0**	**1**	**4**
	rel std dev	**3.58%**	**8.53%**	**0.36%**	**2.79%**	**1.09%**	**0.42%**	**1.47%**	**0.91%**	**0.81%**	**5.02%**	**0.00%**	**62.65%**	**3.42%**
GORDON-ARGILLITE SCH	5/3/2006 19:53	130.07	177.851	43.402	21.303	132.893	139.107	123.266	20.232	523.929	33.601	14.173	16.154	23.356
GORDON-ARGILLITE SCH	5/2/2006 3:58	127.911	176.316	42.97	21.284	132.994	139.401	124.006	20.131	525.691	33.786	13.655	16.4	23.726
GORDON-ARGILLITE SCH	5/1/2006 16:32	128.102	177.62	42.921	21.279	132.847	138.794	123.647	20.33	517.277	33.662	13.206	15.771	23.334
	avg	**129**	**177**	**43**	**21**	**133**	**139**	**124**	**20**	**522**	**34**	**14**	**16**	**23**
	rel std dev	**0.93%**	**0.47%**	**0.61%**	**0.06%**	**0.06%**	**0.22%**	**0.30%**	**0.49%**	**0.85%**	**0.28%**	**3.54%**	**1.97%**	**0.94%**
GORDON-WULING PRISC	5/3/2006 21:48	138.817	106.667	43.996	25.894	109.949	157.823	107.125	19.693	485.55	29.528	13.833	16.33	23.349
GORDON-WULING PRISC	5/2/2006 2:04	137.68	106.498	43.346	25.446	109.167	157.657	107.192	19.582	484.765	29.633	13.102	16.559	23.292
GORDON-WULING PRISC	5/1/2006 14:37	137.826	106.481	43.234	25.405	109.124	157.013	106.6	19.483	483.7	29.526	13.777	15.173	22.955
	avg	**138**	**107**	**44**	**26**	**109**	**157**	**107**	**20**	**485**	**30**	**14**	**16**	**23**
	rel std dev	**0.45%**	**0.10%**	**0.95%**	**1.06%**	**0.42%**	**0.27%**	**0.30%**	**0.54%**	**0.19%**	**0.21%**	**3.00%**	**4.64%**	**0.92%**